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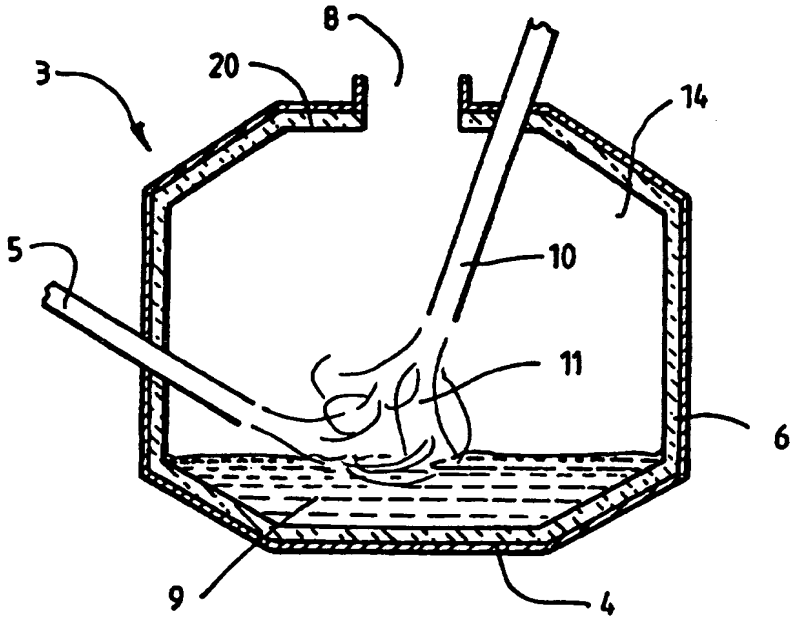
With international search report.

(54) Title: A METHOD OF PRODUCING METALS AND METAL ALLOYS

(57) Abstract

A method and an apparatus for producing metals and metal alloys from metal oxides in a metallurgical vessel containing a molten bath having a metal layer and a slag layer is disclosed. The method is characterised by injecting a carrier gas and a solid carbonaceous material and/or metal oxides into the molten bath from a side of the vessel that is in contact with the molten bath or from above the molten bath so that the solids penetrate the molten bath and cause molten metal to be projected into the gas space above the molten bath to form a transition zone. The method is also characterised by injecting an oxygen-containing gas into the gas space to post-combust reaction gases released from the molten bath into the transition zone.



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A METHOD OF PRODUCING METALS AND METAL ALLOYS

The present invention relates to a method of producing metals and metal alloys, in particular although by no means exclusively iron and iron alloys, from metal oxides, such as ores and partly reduced ores, in a metallurgical vessel containing a molten bath.

A known method of producing molten iron from iron ore is described generally as the HIsmelt Process and is based on forming a bath of molten iron and slag in a smelt reduction vessel which comprises:

i. bottom tuyeres for injecting solid carbonaceous material and a carrier gas into the molten bath;

ii. top tuyeres for injecting iron ore, which may be pre-heated and/or partially reduced iron ore, into the molten bath from above the surface of the molten bath; and

iii. top tuyeres for injecting air into the space above the surface of the molten bath to after-burn or post-combust reaction gases, such as CO and H_2, released from the molten bath.

In accordance with the HIsmelt Process, the carbonaceous material acts as a reductant and an energy source.

An important feature of the HIsmelt Process is to form a transition zone in the gas space above the molten

bath surface in which there are ascending and thereafter descending droplets or splashes of molten metal and slag which mix with reaction gases from the molten bath, top blown hot air, and the reaction gases from afterburning. The purpose of the transition zone is to facilitate the transfer to the molten bath of heat that is released by afterburning reaction gases from the molten bath. In accordance with the HIsmelt Process, the transition zone is formed by vigorous bottom injection of carbonaceous material and carrier gas into the molten bath which causes droplets and splashes of molten metal and slag to be projected from the molten bath.

A recent development of the HIsmelt Process is described in Australian patent application 48938/93 entitled "A Method for Intensifying the Reactions in Metallurgical Reaction Vessels" in the name of Technological Resources Pty Limited. The Australian patent application claims a priority date of 16 October 1992 from German patent application 4234974.

The Australian patent application describes that an improvement in heat transfer efficiency of the HIsmelt Process can be obtained by controlling the bottom injection of carbonaceous material and carrier gas so that the transition zone is defined by a "fountain" of splashes and droplets of molten iron and slag. The paragraph bridging pages 5 and 6 of the patent specification of the Australian patent application describes that:

> "The invention is also based on the finding that the reactions in metallurgical reaction vessels are increased if fractions of the smelt are ejected from the bath like a fountain through the amount of gas introduced via the under-bath tuyeres and these fractions of the smelt move within the gas space in the form of drops,

splashes and large particles of the smelt on ballistic trajectories that are only stopped when the smelt fractions hit the vessel wall or the smelt itself, collide with other smelt fractions or are drawn in by the oxidising gases blown onto the bath in the form of free jets."

An object of the present invention is to provide an alternative method of generating a fountain-like transition zone.

According to the present invention there is provided a method of producing metals and metal alloys from metal oxides in a metallurgical vessel containing a molten bath, the molten bath comprising a metal layer and a slag layer on the metal layer, the method being characterised by the steps of:

i. injecting a carrier gas and solid carbonaceous material and/or metal oxides and/or other solid material into the molten bath through a section of a side of the vessel that is in contact with the molten bath and/or from above the molten bath so that the carrier gas and solid carbonaceous material and/or metal oxides and/or other solid material cause molten metal to be projected into a space above the surface of the molten bath to form a transition zone; and

ii. injecting an oxygen-containing gas into the space above the molten bath surface to afterburn reaction gases released from the molten bath into the transition zone.

The term "transition zone" is understood herein

to mean a zone above the molten bath in which there are ascending and thereafter descending droplets or splashes of molten metal.

The present invention is based on the realisation that it is possible to form the transition zone of the HIsmelt Process, without loss of performance and with engineering advantages, by injecting carrier gas and carbonaceous material and/or metal oxides and/or other solid material into a molten bath through a section of a side of a metallurgical vessel that contacts the molten bath and/or from above the surface of the molten bath.

As a consequence, the present invention makes it possible to avoid using bottom injection of carbonaceous material and carrier gas to form the transition zone and the engineering difficulties associated with such bottom injection. One engineering difficulty is that the use of bottom tuyeres makes it necessary to mount the metallurgical vessel for rotation about an axis so that the bottom tuyeres can be rotated clear of the molten bath at turn-down. Furthermore, if bottom tuyeres are eliminated, a much simpler, and more robust, furnace bottom construction is possible.

The present invention is also based on the realisation that, in situations where step (i) includes injecting carbonaceous material, injection through a tuyere as proposed is an effective means of achieving the desirable objective of ensuring that carbonaceous material penetrates the molten bath, and in particular the metal layer of the molten bath.

It is preferred that step (i) comprises injecting the carrier gas and carbonaceous material and/or metal oxides and/or other solid material through the side section of the vessel or from above the surface of the molten bath

with sufficient momentum to penetrate the molten bath and cause molten metal to be projected into the space above the molten bath surface to form the transition zone.

It is preferred that step (i) comprises injecting the carrier gas and carbonaceous material and/or metal oxides and/or other solid material into the molten bath to cause molten metal to be projected into the space above the molten bath surface in a fountain-like manner.

The carbonaceous material may be any suitable carbonaceous material, in solid, liquid or gaseous form.

The metal oxides may be in any suitable form. For example, the metal oxides may be in the form of ores and/or partly reduced ores. The degree of pre-reduction of the ores may range from relatively low (eg to FeO) to relatively high (70-90% metallisation).

The metal oxides may be pre-heated.

The other solid material may be any suitable material, such as, by way of example, fluxes or slag forming agents.

The carrier gas may be any suitable carrier gas.

It is preferred that the carrier gas be an oxygen-deficient gas.

It is preferred that the carrier gas comprise nitrogen.

The carrier gas may comprise waste process gas released from the vessel which has been used, by way of example, to partially reduce metal oxides that subsequently are transferred to the vessel.

The oxygen-containing gas may be any suitable gas such as, but not limited to, air or oxygen enriched air.

It is preferred that the oxygen-containing gas be air.

It is preferred particularly that the air be preheated.

According to the present invention there is also provided an apparatus for producing metals and metal alloys from metal oxides comprising:

i. a metallurgical vessel for containing a molten bath, the vessel having a base, a side wall, a roof, and a gas outlet;

ii. a first tuyere for injecting an oxygen-containing gas into a space in the vessel above the molten bath; and

iii. a second tuyere above the molten bath or in a section of the side of the vessel that is in contact with the molten bath for injecting a carrier gas and solid carbonaceous material and/or metal oxides and/or other solid material into the molten bath to cause molten metal to be projected into a space above the surface of the molten bath to form a transition zone.

The term "tuyere" is understood herein to include any means for injecting solids and/or gases into a metallurgical vessel.

An outlet end of the second tuyere may be positioned above the surface of the molten bath or may be submerged in the molten bath.

It is preferred particularly that the second tuyere be positioned to direct the carrier gas and carbonaceous material and/or metal oxides and/or other solid material into the molten bath so that the carrier gas and carbonaceous material and/or metal oxides and/or other solid material can cause molten metal and slag in the molten bath to be projected from the molten bath in a fountain-like manner.

The tuyeres may be any suitable configuration.

It is preferred, although by no means essential, that the tuyeres be water-cooled.

The present invention is described further by way of example with reference to the accompanying drawings in which:

Figure 1 is a vertical section through one embodiment of a metallurgical vessel in accordance with the present invention for carrying out an embodiment of the method of the present invention; and

Figure 2 is a vertical section through another embodiment of a metallurgical vessel in accordance with the present invention for carrying out the embodiment of the method of the present invention.

The following description is in the context of smelting iron ore to produce molten iron and it is understood that the present invention is not limited to this application and is applicable to any suitable metallic ores and/or concentrates.

The figures illustrate, albeit in simplified, schematic form, two embodiments of a wide range of possible embodiments of an apparatus for smelting iron ore in

accordance with the present invention.

With reference to the figures, each apparatus comprises a metallurgical vessel 3 having a metal shell and a lining of refractory material which is adapted to retain a bath 9 of molten iron and slag. Each vessel 3 comprises a bottom 4, a cylindrical side wall 6, a roof 20, and a gas outlet 8.

The apparatus in Figure 1 comprises a single tuyere 5 in the side wall 6 of the vessel 3 which is arranged to extend into the vessel 3 to a position at which, in use, the open end of the tuyere 5 is a short distance above the surface of the molten bath 9. The apparatus in Figure 2 comprises two diametrically opposed tuyeres 5 in the side wall 6 of the vessel 3. In this embodiment, the open ends of the tuyeres 5 are substantially flush with the inner surface of the side wall 6. As with the arrangement shown in Figure 1, the open ends of the tuyeres are a short distance above the surface of the molten bath 9. It is noted that this is not an essential feature of the present invention, and the open ends may be submerged in the molten bath 9.

In both embodiments, the tuyeres 5 are angled downwardly toward the surface of the molten bath 9.

With further reference to the figures, each apparatus further comprises a tuyere 10 extending generally vertically into the vessel 3 through the roof 20.

In accordance with an embodiment of the method of the present invention, the operating conditions are selected so that coal and iron ore are entrained in a suitable carrier gas, such as nitrogen, and are injected through the tuyere(s) 5 into the molten bath 9 containing molten iron and slag with sufficient momentum to penetrate

the molten bath 9 and to cause splashes and droplets of molten iron and slag to be projected upwardly from the surface of the molten bath 9 in a fountain-like manner to form a transition zone 11 in a space 14 in the vessel 3 above the molten bath surface.

Further, a suitable oxygen-containing gas, such as hot air or oxygen enriched air, is injected via the top tuyere 10 into the vessel 3 for the purpose of afterburning reaction gases, such as CO and H_2 that are released from the molten bath 9 into the space 14 and otherwise would be discharged from the vessel 3 via the gas outlet 8.

There are number of factors that affect the formation of the transition zone 11 and these include, by way of example:

i. the diameter of the tuyere(s) 5;

ii. the position (including the angle) of the tuyere(s) 5 with respect to the surface of the molten bath 9;

iii. the momentum of the stream of coal/ore/carrier gas/other solid material injected through the tuyere(s) 5; and

iv. the number of the tuyere(s) 5 and the size of the vessel 3.

With regard to item (ii), in the context of the preferred embodiment shown in Figures 1 and 2, the tuyere(s) 5 may be located in the side wall 6 of the vessel 3 at any position above or below a suitable reference surface of the molten metal bath 9 provided that the angle of injection and the other factors noted above are such that the stream(s) of coal/ore/carrier gas injected, in

use, through the tuyere(s) 5 can penetrate the molten bath 9 as required to cause splashes and droplets of molten iron and slag to be projected from the molten bath 9 to form as a fountain to form the transition zone 11. One suitable reference surface may be the quiescent level of the molten bath 9, i.e. the level of the molten bath prior to injection of materials into the vessel 3. Whilst not wishing to be limited to any specific dimensions, typically, the open end(s) of the side tuyere(s) 5 may be in the range of 0.5 metres above to 0.5 metres below the reference surface of the molten bath 9.

With regard to item (iii), the momentum of the stream of coal/ore/carrier gas injected through the tuyere(s) 5 is dependent on a number of factors including, but not limited to, the velocity of the stream, the solids loading of the stream, and the required size of the transition zone 11.

In any given situation, an optimum set of operating conditions can be determined by consideration of the above (and other relevant) factors.

As is discussed above, it is believed by the applicant that the method and apparatus of the present invention make it possible to simplify the engineering associated with bath smelting processes where after-burning is achieved in the gas space above the molten bath, such as the HIsmelt Process.

In addition, it is believed by the applicant that the method and apparatus of the present invention make it possible to use relatively wide diameter tuyeres 5 which would provide an additional advantage of the present invention of minimising the risk of blockage and making it possible to inject a wider size range of coal and/or ore through the tuyeres 5.

Many modifications may be made to the embodiments of the method and the apparatus described above with reference to the drawings without departing from the spirit and scope of the present invention.

By way of example, whilst the preferred embodiments described above include a cylindrical vessel 3, it can readily be appreciated that the present invention is not so limited and may be any suitable shape of pressurised or unpressurised vessel.

Furthermore, whilst the preferred embodiments are based on the use of coal/ore/carrier gas to provide sufficient momentum, the present invention is not so limited and extends to the separate use of coal or ore with a suitable carrier gas.

Furthermore, as indicated previously, whilst the tuyeres 5 of the preferred embodiments are positioned so that the open ends of the tuyeres 5 are above the surface of the molten bath, the present invention is not so limited and extends to arrangements in which the open ends of tuyeres 5 are submerged in the molten bath 9.

Furthermore, whilst the tuyeres 5 of the preferred embodiments are positioned in the sides 6 of the vessel 3, the present invention extends to arrangements in which the tuyeres 5 are arranged to extend into the vessel through the roof 20.

Finally, whilst the tuyere 10 for oxygen-containing gas injection shown in the figures extends through the roof 20 in a generally vertical orientation, the present invention is not so limited and the tuyere 10 may be positioned in any suitable location to efficiently after-burn reaction gases released from the molten bath 9.

CLAIMS:

1. A method of producing metals and metal alloys from metal oxides in a metallurgical vessel containing a molten bath, the molten bath comprising a metal layer and a slag layer on the metal layer, the method being characterised by the steps of:

i. injecting a carrier gas and solid carbonaceous material and/or metal oxides and/or other solid material into the molten bath through a section of a side of the vessel that is in contact with the molten bath and/or from above the molten bath so that the carrier gas and solid carbonaceous material and/or metal oxides and/or other solid material cause molten metal to be projected into a space above the surface of the molten bath to form a transition zone; and

ii. injecting an oxygen-containing gas into the space above the molten bath surface to afterburn reaction gases released from the molten bath into the transition zone.

2. The method defined in claim 1 wherein step (i) comprises injecting the carrier gas and carbonaceous material and/or metal oxides and/or other solid material through the side section of the vessel or from above the surface of the molten bath with sufficient momentum to penetrate the molten bath and cause molten metal to be projected into the space above the molten bath surface to form the transition zone.

3. The method defined in claim 1 or claim 2 wherein step (i) comprises injecting the carrier gas and

carbonaceous material and/or metal oxides and/or other solid material into the molten bath to cause molten metal to be projected into the space above the molten bath surface in a fountain-like manner.

4. The method defined in any one of the preceding claims wherein the carbonaceous material is any suitable carbonaceous material, in solid, liquid or gaseous form.

5. The method defined in any one of the preceding claims wherein the metal oxides are in the form of ores and/or partly reduced ores.

6. The method defined in any one of the preceding claims wherein the metal oxides are pre-heated.

7. The method defined in any one of the preceding claims wherein the other solid material is any suitable material, such as, by way of example, fluxes or slag forming agents.

8. The method defined in any one of the preceding claims wherein the carrier gas is an oxygen-deficient gas.

9. The method defined in claim 8 wherein the carrier gas comprises nitrogen.

10. The method defined in claim 8 wherein the carrier gas comprises waste process gas released from the vessel which has been used, by way of example, to partially reduce metal oxides that subsequently are transferred to the vessel.

11. The method defined in any one of the preceding claims wherein the oxygen-containing gas is air.

12. The method defined in claim 11 wherein the air is preheated.

13. An apparatus for producing metals and metal alloys from metal oxides comprising:

i. a metallurgical vessel for containing a molten bath, the vessel having a base, a side wall, a roof, and a gas outlet;

ii. a first tuyere for injecting an oxygen-containing gas into a space in the vessel above the molten bath; and

iii. a second tuyere above the molten bath or in a section of the side of the vessel that is in contact with the molten bath for injecting a carrier gas and solid carbonaceous material and/or metal oxides and/or other solid material into the molten bath to cause molten metal to be projected into a space above the surface of the molten bath to form a transition zone.

14. The apparatus defined in claim 13 wherein an outlet end of the second tuyere is positioned above the surface of the molten bath.

15. The apparatus defined in claim 13 wherein an outlet end of the second tuyere is submerged in the molten bath.

16. The apparatus defined in any one of claims 13 to 15 wherein the second tuyere is positioned to direct the carrier gas and carbonaceous material and/or metal oxides and/or other solid material into the molten bath so that the carrier gas and carbonaceous material and/or metal

oxides and/or other solid material cause molten metal and slag in the molten bath to be projected from the molten bath in a fountain-like manner.

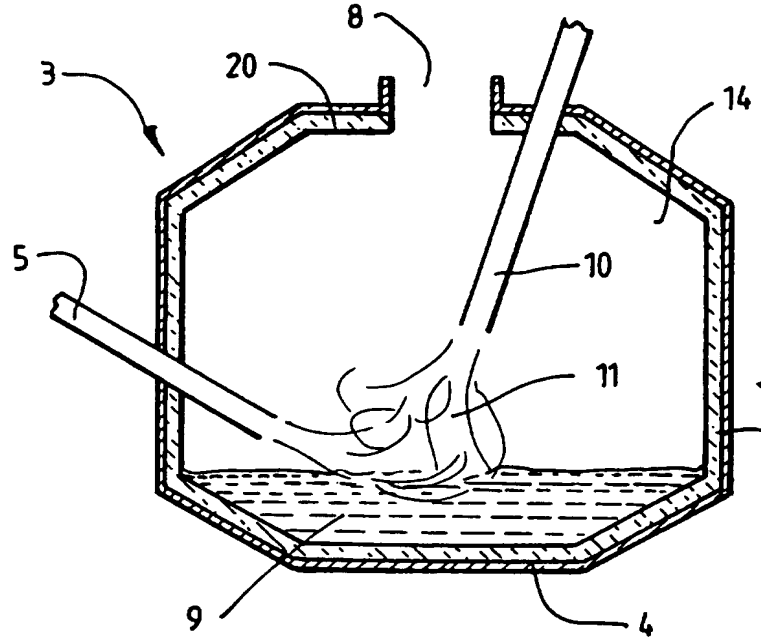

FIG. 1.

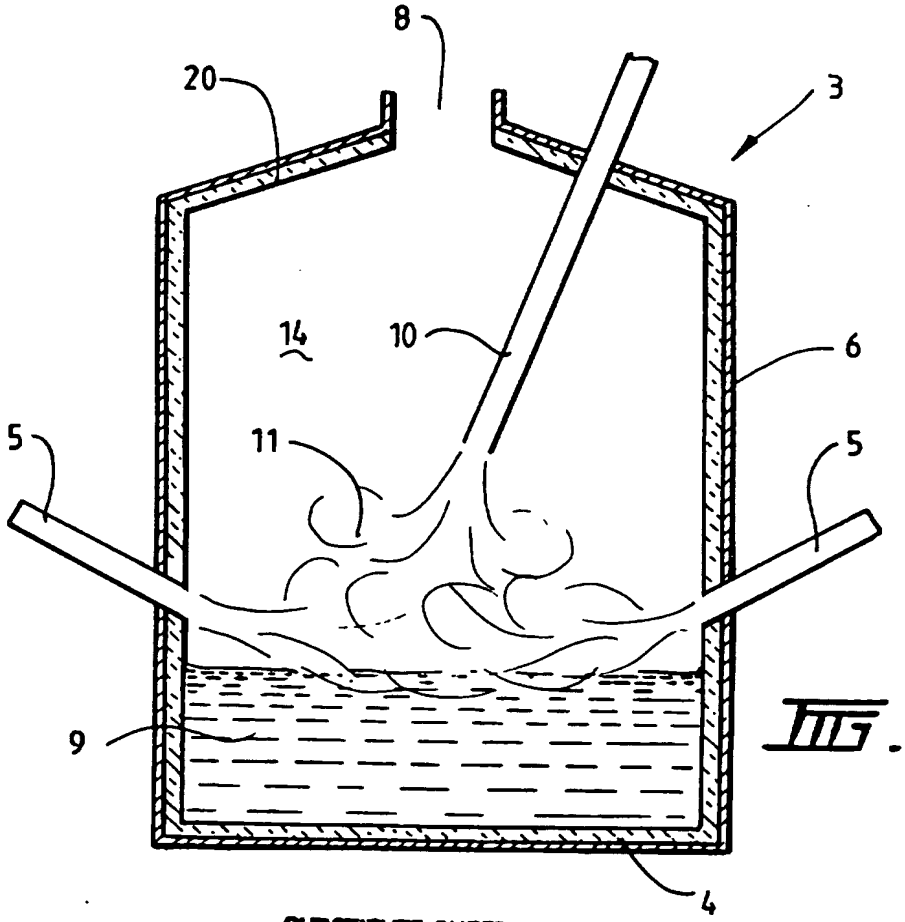

FIG. 2.

INTERNATIONAL SEARCH REPORT

International Application No.
PCT/AU 96/00197

A. CLASSIFICATION OF SUBJECT MATTER

Int Cl[6]: C21B 13/00 C21C 5/32 F27D 3/18

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)
C21B 13/00 C21C 5/32 5/34 5/35 F27B 14/16 F27D 3/18

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched
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Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)
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JAPIO: as for WPAT

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	EP 446860 A (CRA SERVICES LIMITED) 18 September 1991 column 4-5	1-16
X	EP 327862 A (KLOCKNER CRA PATENT GMBH) 16 August 1989 columns 5-7	1-16
A	EP 79182 A (BRITISH STEEL CORPORATION) 18 May 1983 entire document	1-16

[X] Further documents are listed in the continuation of Box C

[X] See patent family annex

* Special categories of cited documents:

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Date of the actual completion of the international search	Date of mailing of the international search report
24 May 1996	3RD JUNE 1996.
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national Application No.
PCT/AU 96/00197

C (Continuation) **DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No
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A	EP 592830 A (TECHNOLOGICAL RESOURCES PTY LTD) 20 April 1994 entire document	1-16
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No.
PCT/AU 96/00197

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Patent Document Cited in Search Report		Patent Family Member					
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INTERNATIONAL SEARCH REPORT

Information on patent family members

International Application No.
PCT/ AU 96/00197

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END OF ANNEX